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THEORY OF THE FORMATION AND STRUCTURE OF QUASI-STELLAR RADIO SOURCES

[Handwritten inscription:

To Dr. A. G. W. Cameron, Convenor of the Conference on the Observational Aspects of Cosmology.

With the author's compliments

/s/ Ozernoy]

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Theory of the Formation and Structure of Quasi-Stellar Radio Sources

ON THE THEORY OF FORMATION AND STRUCTURE OF QUASARS

Annotation

A qualitative consideration is given for a number of problems pertaining to the nature of quasi-stellar radio sources or quasars. The basis is provided for the hypothesis that the central regions of quasars, just like the nuclei of galaxies, are, in a specific stage of evolution, massive diffuse formations with large magnetic fields and stormy movements. From the preceding state (about which very little is yet known) in which there was a marked deviation of matter from a thermodynamic equilibrium it is convenient to pass over to the state of chaotic movement in which disequilibrium is effectively eliminated by the turbulent processes of transfer.

To draw an idealized diagram of the diverse phenomena which occurred in the nuclei of galaxies, and, especially in the central parts of the quasars, consideration is given to a quasi-stationary configuration in the equilibrium of which the magnetic field plays a prominent part; such a configuration is termed a "magnetoid."

The source of powerful radiations from quasars is, in the final analysis, gravitational energy given off in the process of the eternal compression of the nucleus. The magnetic field is an important intermediate agent.

Given is a precise solution of the equation of magnetic hydrodynamics which describes the stationary rotation of fluid along the lines of force of a toroidal magnetic field. This solution, which gives reality to one of the possible types of magnetoids, is used for evaluating the characteristic time of repetition of the picture of circulating movements of the plasma in more complex models of a magnetoid. If such a quasi-periodic movement actually

occurs in the nuclei of quasars, one might expect some variability of the energy flow irradiated by the quasar. The variability of radiation observed in the optical band (undoubtedly there are variations in flow in other spectral intervals also) serves, to some degree, as a confirmation of the ideas developed.

In the stage of the global quasi-equilibrium of the nucleus allowance is made for various local ejections and flows of substances associated with the active regions of the quasar.

The advantage of the proposed approach is its explanation of the basic peculiarities of quasi-stellar radio sources - the powerful flux given off for a rather prolonged time if variability is present. In the scheme presented here much must of necessity remain hypothetical for the time being.

INTRODUCTION

[Report given at the 2d Soviet gravimetric conference (Tbilisi, Apri 1965).]

The question of the paths of transition of metagalactic objects to their observed state has changed in recent years from a purely speculative question to an object of intensive scientific study.

The evidence of continuing activity of galactic nuclei[1], the violent processes in radio galaxies[2], the discovery of comparatively young intergalactic condensations[3] -- all these point to the dissatisfaction of the old point of view relative to the active processes in the galaxies and the formation of all galaxies in the very earliest stages of expansion of the Friedmanovskiy world. The discovering in 1963 of quasi-stellar radio sources (so-called quasars) testifies directly to the recent radical cataclysm in these systems.

Summarizing the observation data, we can point to the following distinguishing characteristics of quasars[4]:

a. Radio emanations from regions of abnormally small angular dimensions;

b. Small dimensions of optical sources compared with radio dimensions; tremendous brightness in the luminous (visible or infrared) band;

c. Variations in the luminous flux (cyclic changes by tens of percentage points for a duration of several years; in the case of the most intensively studied object, 3C 273, there were found, in addition, sporadic changes of short duration as well as a certain secular decrease in flux).

Comparing the observed data pertaining to quasars and radio galaxies we concluded[5] that quasi-stellar sources are not "monsters" among radio galaxies, but rather they represent an active phase of evolution of Seyfert galaxies[6*]. To be sure, the presence of specific "ejections" in many quasars and certain

* Recently, I. S. Shklovskiy cited some interesting supplemental arguments pointing to the nearness of quasars to the Seyfert galaxies.

other peculiarities exclude a total analogy with the Seyfert galaxies.

The fundamental questions pertaining to the nature of quasars consists of the following:

1. What is the reason for the generation in a volume smaller than or of the order of a galactic nucleus of a mighty radiation under observation conforming in a radio band to an ordinary galaxy and in the light band exceeding by tens and hundreds of times the radiation given off by a galaxy?

2. What is the nature of the variation in a luminous flux?

More than likely, these questions are closely related[8,9]. In the following, an attempt will be made to provide answers to these questions.

I. System of Gravitational Condensation and Formation of Quasars

In conformance with present day astrophysical concepts the formation of galaxies and their clusters is related to the gravitational condensation of diffuse masses[10]. The variety of types in the metagalactic population can be explained on the basis of various initial conditions[10,11]. These include the thermal rate of condensation; the relationship between the gravitational energy Ω, kinetic energy E_k, thermal energy E_t, rotational energy E_w, turbulent energy E_{turb}, and the energy E_m as well as the geometry of the magnetic field. It is also convenient to consider from this point of view the formation of the nuclei of quasi-stellar objects, after indicating their place in the system of gravitational condensation. Depending on the original relationship between Ω, E_k, E_t, E_w, E_{turb}, E_m there come into being two qualitatively different situations during the course of evolution of a condensing cloud -- either uninterrupted condensation in a singular sphere during the course of which the oscillation [raskachka] of perturbations is small, or there is instability of condensation, fragmentation into smaller masses, and the formation of a turbulent "ball."

In the latter case (when we have instability of an uninterrupted condensation due to oscillation [raskachka] of perturbation) several possibilities exist. Let ρ_ω be the density at which, during the course of contraction, the centrifugal forces balance the gravitational forces; ρ_m is the density at which gravity is balanced, mainly, by the tension of the magnetic lines of force; ρ_t - the density at which the gas pressure becomes substantial; ρ_* is the density at which the medium fragments into sub-systems. Depending on the initial relationships between Ω and E_w, E_m, E_t the following more important instances are possible during contraction:

$$\text{I.} \quad \rho_\omega \ll \min\{\rho_*, \rho_m, \rho_t\}$$

This possibility can be realized given a large initial rotation and the absence of total freezing of the medium. Contraction is slowed down and continues in the direction of the axis of rotation with a speed governed by the loss of the angular moment down to fragmentation.

$$\text{II.} \quad \rho_* \ll \min\{\rho_\omega, \rho_m, \rho_t\}$$

During the process of hydrodynamic contraction star formation occurs. If, during the evolution, the fragments have gathered sufficient moment, the shape of the star cloud will approximate that of a sphere. Thus, possibly, spherical clusters and spherical galaxies are formed.

$$\text{III.} \quad \rho_t \ll \min\{\rho_\omega, \rho_m, \rho_*\}$$

Rotation was not present originally or was lost. The cloud becomes opaque and during a certain period of time exists as a super star.

$$\text{IV.} \quad \rho_m \ll \min\{\rho_\omega, \rho_*, \rho_t\}$$

The magnetic field played an important role from the very outset, and during the course of contraction it was intensified by rotation and chaotic movements.

A more detailed analysis of possible situations during contraction of diffuse masses is contained in [11].

As indicated in [12], case IV may be directly related with the phenomena of radio galactic and quasi-stellar radio sources. In the quasi equilibrium existence of central regions of galaxies accompanied by periodic active processes the magnetic field plays an essential role, and the development of instability in the contracting megnetoplasmic configuration may cause turbulence. The specifics of the evolutionary path, the result of which was the formation of central, active regions, which underwent eruptions from time to time, consist in the fact that the initial macroscopic movements not only did not dampen but eventually passed over to a quasi-stationary turbulent movement of the magnetoactive plasma. We shall term the quasi-stationary configuration, in the balance of which magnetic forces play an important role, the magnetoid.

2. The Magnetoid

The problem of turbulence, given a powerful magnetic field, where, in addition, it is necessary to take into account the self gravitation of the turbulent plasma, is far from a complete solution as we know. Furthermore, in considering dissipation it is essential to take into account, along with the usual or magnetic viscosity, the "viscosity" of the relativistic particles carrying off energy and impulse. Hence, we shall restrict ourselves merely to qualitative considerations whose aim, basically, is to show the possibility and importance of the phenomena mentioned to the central regions of galaxies and quasars.

Let us first consider the limiting case of a fully regulated magnetic field.

Equations describing the movement of an ideal, infinitely developing contracting fluid in a non relativistic region consist of:

$$\frac{\partial \vec{u}}{\partial t} + (\vec{u}\nabla)\vec{u} = \frac{1}{4\pi\rho}[\operatorname{rot}\vec{H}\times\vec{H}] - \frac{1}{\rho}\nabla p + \nabla\varphi \tag{1}$$

$$\frac{\partial \vec{H}}{\partial t} - \operatorname{rot}[\vec{u}\times\vec{H}] = 0 \tag{2}$$

Simple type movements, satisfied by equation (1) and (2), are movements that are collinear with the magnetic field

$$\vec{u} = \pm\frac{\vec{H}(\vec{r})}{(4\pi\rho)^{1/2}} \qquad (\rho = const), \tag{3}$$

and

$$\nabla\left(\frac{p}{\rho} + \frac{|\vec{H}|^2}{8\pi\rho} - \varphi\right) = const \tag{4}$$

For such movements there is at each point an equality between the density of the kinetic and magnetic energies, regardless of the spatial structure of the magnetic field.

An interesting special solution (1) - (2) is the stationary rotation of plasma along the force lines of a toroidal magnetic field $\vec{H} = \{0, H_\varphi, 0\}$. With $\vec{u} \parallel \vec{H}$ even with finite conductivity we have $\Delta \vec{H} = 0$, whence

$$H_\varphi = a_1 r + a_2 r^{-1} \qquad (5)$$

A restriction of the field on the axis of rotation (r = 0) gives $a_2 = 0$. By using a condition of "glueiness" [prikleyennost'] we can say $H_\rho = b\rho r$, $b_\rho = a_1/\rho$ = idem throughout the entire volume of the magnetoid. From (1), ignoring the factor of contraction, we find the angular frequency of rotation

$$\omega = \left(\frac{b^2}{2\pi} \rho + \frac{4\pi G}{3} \rho \right)^{1/2}, \qquad (6)$$

which is a constant for all points of the configuration. A more general situation in which the rotation is not uniform occurs when contraction is taken into account.

Solution (5) - (6) is an example from the class of movements that are parallel to the field for which the conditions for equal distribution of kinetic and magnetic energy are not fulfilled.

We shall concern ourselves with the question of magnetoid stability, the movements in which are directed through the field and which satisfy relationship (3).

Virial's Theorem

$$2E_k + E_m + 3E_t + \Omega = 0$$

under conditions (3) gives

$$E_m + E_t + \frac{1}{3}\Omega = 0$$

from which the upper limit of magnetic energy

$$E_m \leq \frac{1}{3} |\Omega| \qquad (7)$$

Taking into account the compressibility the criteria of stability with respect to pulsational oscillations are a function of γ. When $\gamma < 4/3$ the magnetoid is unstable for any $E_m/|\Omega|$. When $\gamma > 4/3$, instability occurs, and if $\xi \equiv E_m/|\Omega|$ exceeds a certain $\xi_*(\gamma)$ it is larger, the greater is . Obviously $\xi_*(4/3) = 0$ (without taking into account the corrections for plasma and OTO).

$\xi_*(\infty) = 1/3$. The numerical variation $\xi_*(\gamma)$ for intermediate values was obtained by Kristian[14]. For γ which exceeds $4/3$ by any perceptible amount, $\xi_*(\gamma)$ does not change markedly. For example, $\xi_*(5/3) = 0.0906$, which is a fourth as great as the maximal possible value $\xi_*(\infty) = 1/3$ which corresponds to a case of an incompressible fluid.

Thus, the magnetoid is pulsation-stable at

$$E_m \leqslant \xi_*(\gamma)\,|\Omega| \tag{8}$$

Apart from the question of global stability of the magnetoid, there is a great interest in the study of local stability with respect to the rearrangement of the lines of force in the magnetic field. Consideration of that problem (taking into account the centrifugal effect, which is added to the magnetic convective instability), that is given elsewhere, shows that beginning at a definite distance the laminar rate of rotation of plasma is convectively unstable. It can be assumed that as a result of instability turbulence will develop; this turbulence is superimposed on a large scale movement. In this case, equilibrium of the magnetoid will be ensured by the gradient of magneto-turbulent pressure. Along with the gathering of vortexes which interact upon one another, various quasi-elastic oscillations may be excited in the magnetoid. The turbulent pulsations of the velocity field are bound through the interaction with the turbulent pulsations of the magnetic field. If the radiation of a magnetoid is magneto-decelerative in nature, the turbulent pulsations of the magnetic field should lead to sporadic fluctuations in the luminous emittance of the object. It appears quite possible that these phenomena of the "flare" type in certain of the quasars observed support the point of view that is being developed[9].

In connection with what has been set forth in the above it may be concluded that currents generated by movements of plasma will produce, in consequence of instability, a disturbance in the uniform distribution of matter in the magnetoid if it previously existed. The electrical field will produce a twisting of the magnetic lines of force into individual "magnetic braids" so that the plasma will be gathered together in the form of fibers wherein the density of matter at the magnetic pole will be considerably greater than on the outside.

Explosion of the nucleus of galaxy M 82 can serve as a confirmation of these ideas. Most characteristic in the picture of the results of an explosion which occurred about $3 \cdot 10^6$ years ago is the vast system of so-called "filaments" directed along the small axis of the galaxy[15] -- regular loops and threads swing in H_α and in a continuum. The filaments display virtually 100% polarization, which can be explained by the existence of a large scale magnetic field oriented along the gas fibers. According to the viewpoint being developed the filaments are the "magnetic braids", which are straightened out during the process of explosive ejection. When the nucleus undergoes an explosion, and given a filamentary structure, expansion of the nucleus may occur as an expansion of the system of magnetic braids, maintaining the cross section of individual jets. In this, the energy loss of relativistic particles on the process of expansion will be virtually nothing. It is interesting to note that only this manner of expansion can be assumed in galaxy M 82 from an analysis of the radiation of its relativistic electrons[16]. Undoubtedly, such a phenomenon is quite general in character and explains the continuing radiation in those instances where one can hardly expect the existence of a source of "acceleration" of electrons, whereas an isotropic adiabatic expansion would have been accompanied by a high loss of energy particles.

We are not concerning ourselves here with a very detailed description of the internal structure of the magnetoid in view of the considerable variety of possible operating rates that depend on the initial and boundary conditions. We shall merely point to the interesting possibility of the existence in a magnetoid of large scale heterogeneities. In particular, if the origin of a magnetoid is tied in with the contraction of a heterogeneous cloud, the formation of a super-mass star -- "a super star" -- is possible. Playing an important part in the balance of such a star is the radiant pressure, in contrast with usual stars, which are kept in equilibrium mainly by the gas pressure gradient. Since gravitational pressure changes with density just like radiant pressure does, ($\sim \rho^{4/3}$) then in the theory of equilibrium and evolution of super-massive stars[17,18] the main aspect seems to be taking into account the smaller corrections (for plasma, OTO effect, and birth of pairs) in the equation of state. For $M \lesssim 5.10^5\ M_{\odot}$ the nuclear liberation of energy makes up for radiation, and the superstar may be in a state of equilibrium. The pulsations of such a superstar are of special interest for future study, because if the star is "magnetically" related to the region of generation of the flux observed, these pulsations can bring about periodic changes in flow[9]. A possible mechanism for de-oscillating the oscillations of a superstar are convections which course through in a magnetic superstar in the form of an oscillating instability[13].

3. The Magnetoid as a Model of a Quasar Nucleus

Making use of data obtained by observation, we shall first get an estimate of a series of basic parameters for quasar nuclei necessary for comparisons with the ideas developed in the foregoing. From an analysis of the radiations emanating from quasar 3C 273, assuming it to be of a magnetic decelerating nature, we previously got [19] some estimates of the intensity of the magnetic field and the minimal energy of the relativistic electrons, taking into account the great importance of Compton losses. At the present time we can assume that the magneto decelerating nature of the radiations emanating from quasar nuclei has been substantiated[20-22]. It has also been demonstrated that the maximum radiation of the nucleus of 3C 273 lies in the infrared and submillimeter ranges[21,22]. Changes in the spectral index of radiation of 3C 273 with $\nu_0 \simeq 10^{13}$ cycles from $\alpha \simeq 2.5$ in the interval $\nu_0 < \nu < 3.10^{12}$ cycles to $\alpha \simeq 0$ with $\nu < \nu_0$ may be tied in, according to I. S. Shklovskiy, with the reabsorption of relativisitic electrons. This circumstance enables us to get a reliable estimate of the linear dimensions of the nucleus of 3C 273. Assuming, in accordance with 21 that F_{ν_0} $6.3.10^{-22}$ erg/cm^2 sec. cycles we find, disregarding the non sphericity of the nucleus and the slight red shift of 3C 273

$$R \simeq 4{,}2 \cdot 10^{15} H^{1/4} \tag{9}$$

Assuming $W_H = \frac{H^2}{8\pi} V = \varkappa_H W_{K.A.}$ and $W_{K.A.} = \varkappa_r W_e$, we have from the theory of magneto-deceleration[23]

$$\frac{H^2}{8\pi} V = \varkappa_r \varkappa_H A(\gamma,\nu) r^2 F_\nu H^{-3/2} \tag{10}$$

We will note that in (10) the presence of heterogeneities is not taken into account. The unknown spatial distribution of electrons and magnetic field makes it necessary here, as in the development of (9), to restrict outselves to a uniform model. The joint solution of (9) and (10) gives us

$$H = \left[6a^{-3} \varkappa_r \varkappa_H A(\gamma,\nu) r^2 F_\nu \right]^{4/17} \tag{11}$$

$$W_{K.A.} = (6a^{-3})^{-6/17} \varkappa_r^{11/17} \varkappa_H^{-6/17} \left[A(\gamma,\nu) r^2 F_\nu \right]^{11/17} \tag{12}$$

in which a is the numerical coefficient in equation (9). In the usual assumptions $\mathcal{X}_r = 10^2$, $\mathcal{X}_* = 1$ (9), (11), (12) give

$$R \simeq 1 \cdot 10^{16}\ \text{см},\ H \simeq 2 \cdot 10^{2}\ \text{эрст},\ W_{\text{к.л.}} \simeq 10^{52}\ \text{erg} \qquad (13)$$

The observed[21] power of radiation of the nucleus of 3C 273 is equal to 9.10^{46} erg/sec in conformance with the rough estimate[19].

The first congruence (13) shows that the upper value of 2.10^{16} cm accepted thus far as the radius of the nucleus of 3C 273 is essentially correct; this value follows from the luminous fluctuations of weekly duration. A more precise value of the magnetic field does not differ very greatly from [19].

We shall consider in greater detail the picture of the central regions of a quasar from the point of view of the ideas developed in Chapters 1 and 2. We shall identify the nucleus of the object with the concept of the magnetoid introduced in the foregoing. The fact of regular changes in the luminous flow from the quasar nucleus testifies to the prime importance attributable to large scale pulsations, the scale of which is of the order of the characteristic dimensions in the entire nucleus. The large scale movements include the basic portion of the kinetic energy of the moving plasma.

Generations of larger scale occur as a result of the evolvement of gravitational energy during the process of secular contraction. The speed of energy liberation is equal to the following:

$$\mathcal{E} \sim {}^{4}\!\mathcal{G} M^2 R^{-2} \dot{R} = 2{,}7 \cdot 10^{43} \left(\frac{M}{10^8 M_\odot}\right)^2 \left(\frac{10^{16}}{R}\right)^2 \dot{R}\ \ \text{erg/sec.}$$

The higher possible value of speed of contraction is given for the nucleus of quasar 3C 273 by inequality $R/\dot{R} > 10^3$ years, in which 10^3 years is the lower limit of age of this object as a result of observation[25]. Assuming $R = 10^{16}$ cm we get $\dot{R} < 10^6$ cm/sec so that the gravitational liberation of energy, with $M = 10^8$ M , which is a conservative estimate, $\mathcal{E} < 10^{49}$ erg/sec.

This upper value is sufficiently great to explain the observed flow of 10^{47} erg/sec from the nucleus of 3C 273 by gravitational energy. Along with this, the upper limit of the rate of contraction is much less than the characteristic speed of movement of plasma in a magnetoid so that the balance of the latter is actually quasi-stationary.

The supersonic movement is accompanied by the appearance of shock waves and the dissipation of energy. The stationary aspect of supersonic turbulence will be evident if the plasma in the interval between the successive appearances of shock waves can return to the non-disturbed state. The criterion governing this possibility is fulfillment of the necessary condition $L/U \gg \tau$, in which $\tau = (n_e C_h)^{-1}$ is the time of relaxation of glow [vysvechyvaniya] $C_h \simeq 4.10^{13}(\frac{T}{10^4})^{-3/4}$ cm^3 sec^{-1}. For the main scale $L/U \sim 10^{16} : 10^9 = 10^7$ sec. Meanwhile, $C_H \simeq 4.10 + 10^{-13}$ for $T = 10^4 + 10^5$ °K and because of the high density ($n \sim 10^{15}$ cm^{-3}) $\tau \sim 10^{-2}$ sec so that the inequality is fulfilled with a certain amount to spare. Computation of the magnetic field decreases the dissipation of energy of turbulent flow*.

To get an estimate of the upper value of the magnetic field in the nucleus of 3C 273 use formula (8) which corresponds to limiting stationary conditions. For a uniform sphere

$$H \leqslant \left[\frac{18}{5} \xi_*(\gamma) G \right]^{1/2} \frac{M}{R^2} \tag{14}$$

Assuming $\gamma = 5/3$, $M = 10^8 M_\odot$, $R = 10^{16}$ cm we determine from (14) $H \leqslant 3.10^5$ erst. It is interesting to note that the difference between this value and an estimate of the field (13) from the magneto deceleration theory of radiation is not as marked. In addition, when taking into account the above-indicated tendency toward a fibrous distribution of the plasma and magnetic field the estimate is increased (13).

* Translator's note: The author apparently intended to use some data in this sentence but forgot to do so.

The effective magnetogasodynamic velocity of sound $C_m = (\gamma \frac{p}{\rho} + H^2/4\pi\rho)^{1/2}$ can attain some very high values in the external layers of the magnetosphere -- it is of the order of the velocity of light. It can therefore be assumed that in the quasar magnetosphere relativistic magnetohydrodynamic waves are propagated. The specific time of passage by these waves through the region of the nucleus is $R/C \simeq 10^6$ sec which is close to the duration of the week-long irregular luminous pulsations observed.

We shall now turn to an explanation of long, periodic (cyclic) changes in luminosity of quasar sources. There is hardly any doubt that the variability in radiation by a quasar is so much a fundamental quality that its mechanism should be given a natural explanation within the framework of concepts regarding the very nature of the central regions of the sources. The idea of the quasar nucleus being a magnetoid enables us to relate the origin of variability with the magnetoturbulent movements in the magnetoid. The period of frequency of large scale movements and changes in the magnetic field associated with them apparently determine the period of variations observed in the luminosity[9]. For a rough estimate in the expected frequency of changes in brightness of the quasar we can turn to formula (6). The latter also gives us the correct value for the time of circulation of the heterogeneity of the magnetic pole in the more complex models, which correspond more closely to reality. The existence of turbulence will result, obviously, in various durations of individual cycles, and to a chaotic change in phase on the observed brightness curve. Utilizing (3) and the approximate value of the mass of the 3C 273 nucleus $M \sim 10^8 M_\odot$ we obtain from (6), as an estimate of the mean period, $T = 2\pi/\omega \sim 5$ years. This is not in too bad agreement with the observed duration of an individual cycle.

In the evolution of the quasar nucleus, the frequency corresponding to the maximum radiation of relativistic electrons also changes. The powerful radiation of quasars can be observed in consequence of this in different spectral regions. We can expect, in particular, that the principal radiation of quasars in the low frequency (meter wave length) band, as well as in the high frequency (optical) section occurs for a lesser period of time than in the intermediate regions. The active processes in the nucleus accompanied by periodic local ejections and flows of gas and particles will result, even in the stage of global quasi-equilibrium of the nucleus, in a non stationary picture of radiation. Due to the various degrees of concentration of matter in the centers of individual quasars, variability can occur in various spectral bands. In particular, reference 9 makes the proposal concerning possible variations of certain quasars in the radio band; this is supported in reference 24.

An alternate possibility for explaining cyclical changes in luminosity of quasi-stellar objects are the variations in a magnetic superstar which modulate the magnetic field in the nucleus of the quasar. The various instances of current variation associated with the conditions of injection of relativistic electrons, as well as the possible explanation of the continuous decrease in luminosity are given in reference 9. The related idea of the pulsating superstar as a reason for the variations in the luminous flux of the superstar as a reason for the variation in the luminous flux of the quasar is also developed in a recent work by Fowler[26]. Pulsations of stars are insured, according to [26], by the inclusion of nuclear sources on contraction to 10^{13} cm with their subsequent inclusion in the process of the pulsed expansion of the surface to 10^{17} cm. Without even going into an analysis of the very possibility of such pulsations, which seems doubtful (an "explosive" scatter may result), one cannot agree with this version. Actually, a change in the dimensions of the radiating region by a factor of 10^4 is difficult to reconcile with the observed 20 + 30% variations in light emissivity. Given such non-linear pulsations, the use in reference 26 of the expressions for the natural frequency of adiabatic pulsations is without foundation. Assuming that the uninterrupted emission of 3C 273 is due to a synchrotronous mechanism, Fowler does not take into account the fact[19] that the life of optical electrons is much shorter than the period of the pulsations. Once they are formed by the shock wave, the relativistic particles soon become luminous and the requirement "twinkle, twinkle, quasistar"[27] can only be satisfied in 10 years. The general objection to a pulsating model of a quasistellar radio source[26,28] consists of the following: we can hardly assume that the entire contents of the quasar are exhausted by the superstar. This is contradicted, particularly, by the presence of a film with a mass that is considerably greater than the maximum possible mass of the superstar[25]*.

Among the other hypotheses regarding the nature of quasars is the idea propounded by Field that the quasar is a spheroidal galaxy in the process of its formation[29]. The source of energy is the process of star formation, primarily the supernova II types. Taking into account recent observations[21], in accordance with which the maximum radiant energy from quasar 3C 273 lies in the submillimeter range so that the present output in the continuous spectrum is over 10^{47} ergs/sec, the process would have to involve a star formation

* It is to be noted that whereas the appearance of the phenomenon of quasistellar sources is recurrent in nature[5,7], and variability is present in all phases between successive bursts, the mechanism of variability is more apt to be associated with the circulating movements in the core and not with the pulsating magnetic superstar because of the comparatively short duration of its existence.

cloud with a mass of up to $10^{12}M_{\odot}$, which is much greater than the ordinary mass of an elliptical galaxy. We should especially pause to consider the source of the light variations observed because an analysis of the property of variability is of exceptional importance in explaining the mechanism of the physical phenomena in quasar cores. The reason for changes in luminosity, according to [29], are these very same eruptions of supernovas. Having remarked on the difficulty of reconciling the comparatively short duration of changes in the brightness of supernovas with the considerable dimension of a condensing protogalaxy, Field deems it possible to by-pass this contradiction by assuming a flux from several independent sources which occupy a vast area. However, the nature of change in the brightness curve of 3C 273 contradicts this hypothesis: a mean curve of all the independent individual curves of brightness of supernovas, very close to a sinusoid, requires some rather improbable properties of the ensemble. Generally, models of quasars based on the assumption of a large number of random events, to wit, random collisions, (e.g., [29,30]) uniformly distributed in time over a period of several tens of years contradict the periodic nature of changes in flux observed.

A more detailed investigation of the picture of variability in quasar 3C 273 based on a statistical analysis of the curve of its brightness and comparing it with theoretical models is given elsewhere[31].

The foregoing demonstrates that an analysis of the various processes in a magnetoid is a possible basis for the formation of a theory about the cores of quasars and for providing an interpretation of the active stages of evolution of galaxies and radio galaxies*. However, a number of important questions was pushed to the side. The strong movements of the plasma and the presence of instability are very favorable to the uninterrupted production of

* A comparison of the functions of luminosity of galaxies and radio galaxies with the function of luminosity of quasars 33 points to the uninterrupted transition between them.

relativistic particles. It is important to discuss cosmic rays as a mechanism of dissipation of energy and rotational moment, and their dynamic role in the source. The thing that remains unclear is how important is the interaction of the magnetoid with the surrounding medium. It is possible that the cores were formed in the early stages of expansion of the metagalaxy and the continuous decrease in external gas is of great importance in the gradual realization of conditions under which explosions occur and particles of matter ejected. If the accretion of the surrounding gas is actually essential to this process, as it is for the stationary stage of evolution of the core, then it should be borne in mind that the very nature of accretion in certain important aspects may be determined by the magnetic field. For example, the field is capable of canalizing the inflowing plasma. In the axially symmetrical wine-glass type configurations or dipole field, the flow of plasma [12] will be mainly along the polar axis. If an ejection occurs during the course of non-stationary accretion[18] its direction will also be a function of the geometry of the magnetic field. An alternate possibility of quasar transition from the state of comparatively slow evolution to a violent phase of explosive scatter of matter is collapse accompanied by the partial ejection of matter. So far, it is unclear in what measure this or the previously indicated possibility most closely approximates the actual situation.

The minimal energy of relativistic electrons necessary to explain the radio emission of the "ejection" (component A) of quasar 3C 273 is about 10^{57} erg[19]. The total energy of cosmic rays and the magnetic field is probably 10^{59} ergs. Thus, if the origin of an "ejection" is related to the explosion of 3C 273-B, of which there can be little doubt, the required discharge of energy is not under 10^{59} ergs. It is interesting to note that the first phase of the explosive scatter may be accompanied by a marked gravitational radiation capable of being registered on the earth[32].

Also related to the explosive stage, it can be assumed, is the origin of the emissional film of the quasar source. Due to the genetic relationship with the quasar magnetosphere, the film should contain a magnetic field and have angular moment. However, due to various instabilities the film apparently becomes fragmented into individual clouds and fibers with the passage of time, and this will render difficult a comparison of the observed picture of emissional lines with the earlier stage of dispersion.

Note: This report is based on reports 12, 9, 11, and 13. Layser[34] recently wrote an article in which the results of these studies were partially repeated. Apparently he did not know about them.

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